



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

NEW MONTHLY AND SEASONAL RAINFALL MAPS OF THE UNITED STATES*

By ROBERT DEC. WARD

Harvard University

INTRODUCTION

In studying any series of monthly and seasonal rainfall maps, it is important to remember that no single chart represents a fixed condition. Each shows a transitional stage between the rainfall of the preceding and that of the following map. The most vivid, as well as the most accurate, conception of the distribution of the rainfall throughout the year is gained by viewing the successive maps as if they were a set of stereopticon pictures. Each picture develops out of the preceding one and dissolves into that which follows. The best way to gain this view is to hang the whole series of maps on a rack, or, if the maps are of small size, to have them all printed or mounted on one sheet. Each chart should then be thought of as a "snapshot" of constantly fluctuating conditions.

It is by no means difficult to familiarize oneself with the essential characteristics of each month's rainfall. The outstanding features may easily be remembered if the types and the chief controls of rainfall are held in mind. Indeed, it almost immediately becomes possible to name the month or season whose rainfall is shown on any chart, although the designation of the map be concealed. This method of study has been successfully used for the past twenty-five years in the writer's course of lectures and laboratory work on the climatology of the United States. For ordinary purposes, in any general study of climatology, only the more important features of the seasonal and monthly rainfalls need consideration. Details as to the actual amounts of rainfall are difficult to remember. A discussion of them is out of place here. Furthermore, such details may readily be secured, when needed, from the official publications of the Weather Bureau.

In a general survey of rainfall distribution throughout the year the seasonal maps may best be taken as the basis of study. They show the larger facts. They cover divisions of the year which are universally recognized as logical and as having human and economic significance. Further, they sufficiently emphasize the essential characteristics of the varying rainfall in different parts of the year without the risk of the confusion which is not unlikely to result from a detailed study of the twelve monthly maps. The latter should, however, by no means be discarded.

* This is the sixth in a series of articles by the present writer on the climatology of the United States. The previous articles were: Climatic Subdivisions of the United States, *Bull. Amer. Geogr. Soc.*, Vol. 47, 1915, pp. 672-680; Rainfall Types of the United States, *Geogr. Rev.*, Vol. 4, 1917, pp. 131-144; Rainy Days and Rain Probability in the United States, *Geogr. Rev.*, Vol. 7, 1919, pp. 44-48; Frost in the United States [a review], *Geogr. Rev.*, Vol. 7, 1919, pp. 339-344; Cloudiness in the United States, *Geogr. Rev.*, Vol. 9, 1920, pp. 347-356.

THE NEW CHARTS

Several sets of monthly and seasonal rainfall maps of the United States have been published.¹ There are certain fundamental objections to them. (1) The number of stations for which data were available was limited. (2) The records did not cover a uniform period and were not reduced to a uniform period. (3) The isohyetal lines were generally drawn with little or no regard to topographic controls. For the climatic section of the "Atlas of American Agriculture" there has recently been prepared a new and very complete series of rainfall charts. The precipitation section of the "Atlas" has not yet been published. In view of a long delay in the issue of the "Atlas," and of the fact that, when it appears, it will not be available for general distribution because of the limited edition necessitated by the high cost of printing, advance publication of several of the new charts has been thought advisable. Thus, the new chart of mean annual precipitation was issued, as a separate "advance" sheet, in January, 1917, and was later also included in the *Monthly Weather Review* for July, 1917.²

More recently, the full set of new monthly and seasonal charts, later to appear in the "Atlas," has been published, in the *Monthly Weather Review*

Lorin Blodget: *Climatology of the United States and of the Temperate Latitudes of the North American Continent*. 536 pp.; maps, diagrs. Philadelphia, 1857. [Rainfall maps for the year and the seasons.]

¹ C. A. Schott: *Tables and Results of the Precipitation, in Rain and Snow, in the United States; and at Some Stations in Adjacent Parts of North America, and in Central and South America*. *Smithsonian Contributions to Knowledge*, No. 222, Vol. 18, pp. 1-175; maps, diagrs. Washington, D. C., 1872. [Rainfall maps for summer, winter, and year.]

Idem: 2nd edit. *Smithsonian Contributions to Knowledge*, No. 353, Vol. 24, pp. i-xx and 1-249; maps, diagrs. Washington, D. C., 1885. [Charts for year and for four seasons.]

H. H. C. Dunwoody: *Charts and Tables Showing Geographical Distribution of Rainfall in the United States*. 51 pp.; maps. *U. S. Signal Service Professional Paper No. 9*. Washington, D. C., 1883. [Monthly and annual charts.]

Idem: *Normal Monthly Rainfall throughout the United States, Based upon 18-Year Normals, Accompanied by a General Description of the Rainfall of the United States*. 10 pp.; maps. *U. S. Signal Service*, Washington, D. C., 1889.

A. W. Greely: *American Weather*. 286 pp.; maps. New York, 1888. [Charts XIII-XV, average rainfall for April, May, and June, based on 18 years' observations.]

M. W. Harrington: *Rainfall and Snow of the United States, Compiled to the End of 1891, with Annual Seasonal, Monthly, and Other Charts*. *Weather Bur. Bull. C*. Washington, D. C., 1894. Atlas and Text. [The monthly maps are reproduced, on a small scale, in "Atlas of Meteorology," 1899, Pl. 24; text, pp. 24-25. The isohyetal lines have been extended into Canada and Mexico.]

A. J. Henry: *Rainfall of the United States, with Annual, Seasonal, and Other Charts*. *Weather Bur. Bull. D*. Washington, D. C., 1897. [Charts of mean annual rainfall for the United States as a whole, and for the eastern United States for April-September.]

See also B. C. Wallis: *The Rainfall of the Northeastern United States; idem*, *The Distribution of the Rainfall in the Eastern United States; idem*, *The Distribution of the Rainfall in the Western United States; idem*, *The Rainfall Régime of the Several States*, *Monthly Weather Rev.*, Vol. 43, 1915, pp. 11-14, 14-24, 170-175, 176-178. [In this series of papers the author presents charts showing the rainfalls for each month by lines of equal departure from the rainfall norm, or "equiplies." The norm is the amount of rainfall that would occur at any place on the assumption that such rainfall is evenly distributed throughout the year. In other words, the usual monthly rainfall averages are expressed as percentages of the annual value at each station. Charts of the wettest and driest months, and of rainfall regions, are given, as well as diagrams of rainfall intensities.]

Idem: *Rainfall and Raininess*, *ibid.*, Vol. 46, 1918, pp. 229-230. [Gives diagrams showing how to convert "equiplies" into isohyets, i.e. raininess into rainfall and vice versa.]

² R. DeC. Ward: *Mean Annual Rainfall of the United States, with Notes on the New Chart of Average Annual Precipitation from the "Atlas of American Agriculture" (Advance Sheet)*, *Monthly Weather Rev.*, Vol. 45, July, 1917, pp. 338-345; chart. [Noted in the *Geogr. Rev.*, Vol. 5, 1918, pp. 325-326.]

for September, 1919.³ These new charts mark a very decided advance over all the earlier ones and are now and will for years remain the "standard" series. They are based on a large number of records (3,600). The stations are well distributed over the country. The records were all reduced to the uniform period of 20 years, from 1895 to 1914, about 1,600 cases being actual averages for this period (short breaks being interpolated), and the remaining 2,000 having been reduced to this same period by the method described in the *Monthly Weather Review*, Vol. 45, May, 1917, pp. 333-335. Further, the isohyetal lines were drawn on hachured base maps, and in locating the lines reasonable attention was paid to topographic controls. The scale of the present maps is 1:12,200,000. They are 11 by 7 inches in size. Isohyets are drawn for 0.5 inch, and then for every inch, or for greater intervals in cases where the lines are crowded.

The charts which accompany the present review (pp. 176, 177) show the mean average precipitation over the United States for the four seasons. They were redrawn, with some slight modifications and a few omissions, from the corresponding charts published in the *Monthly Weather Review*.

THE LARGER FACTS BROUGHT OUT ON THE CHARTS

A general glance at the new maps brings out three striking facts. (1) On the Pacific coast there is a well-defined seasonal migration, northward and southward, of a zone of rainfall which, in some months, may be considered to overlap the Sierra Nevada-Cascade barrier and expand over the northern and southern Plateau areas. These rain conditions are associated with the poleward and equatorward migration of the storm belt, as well as with seasonal changes in temperature over the land which offer the best opportunities for condensation in winter. (2) Over an extended area between the Rocky Mountains and the Mississippi River the rainfall lines advance northward and westward in spring and early summer and retreat southward and eastward in late summer and autumn. That is the conditions favorable for heavier rainfalls move from the Gulf of Mexico up the Mississippi Valley and out over the Plains and then back again. These fluctuations are associated with the development, as the continent warms, of a system of inflowing warm winds, carrying abundant moisture, and with the gradual replacement of this régime, as the continent cools, by a system of outflowing winds. (3) The eastern half of the country shows less difference between the rainfalls in the several months than the western. The districts of greatest fluctuation are along the southern Atlantic and Gulf coasts. In the eastern sections, the decreased cyclonic rainfall of the warmer months is largely or wholly compensated by frequent summer thunderstorms, while along the southern coasts West Indian hurricanes give heavy

³ J. B. Kincer: The Seasonal Distribution of Precipitation and its Frequency and Intensity in the United States, *Monthly Weather Rev.*, Vol. 47, September, 1919, pp. 624-631; charts. [Brief reference was made to this publication in the *Geogr. Rev.*, Vol. 9, 1920, pp. 67-68.]

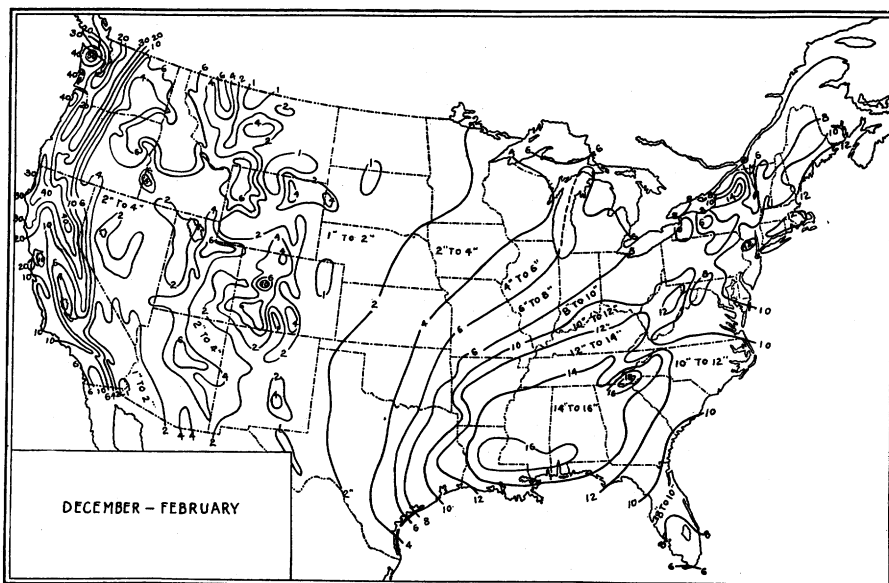


FIG. 1—Map showing the average winter rainfall of the United States. Scale, 1:45,000,000.

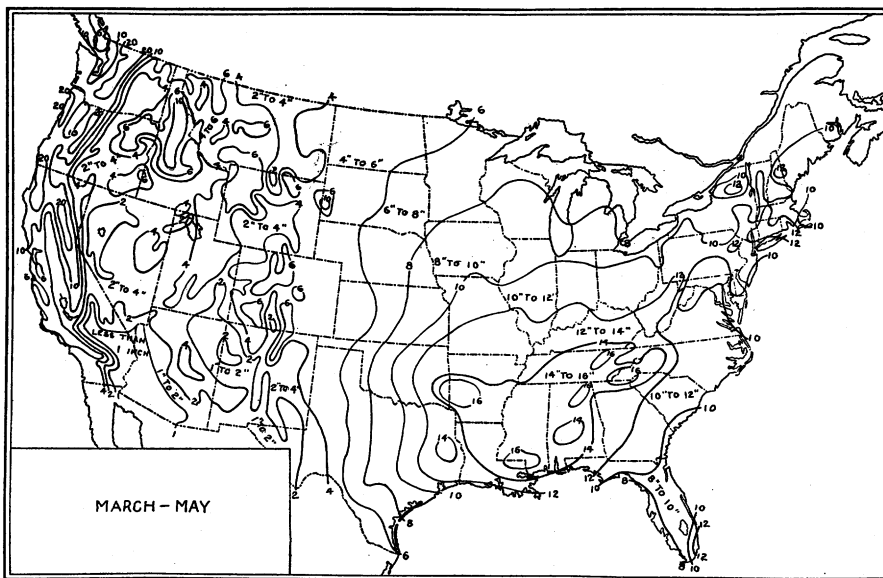


FIG. 2—Map showing the average spring rainfall of the United States. Scale, 1:45,000,000.

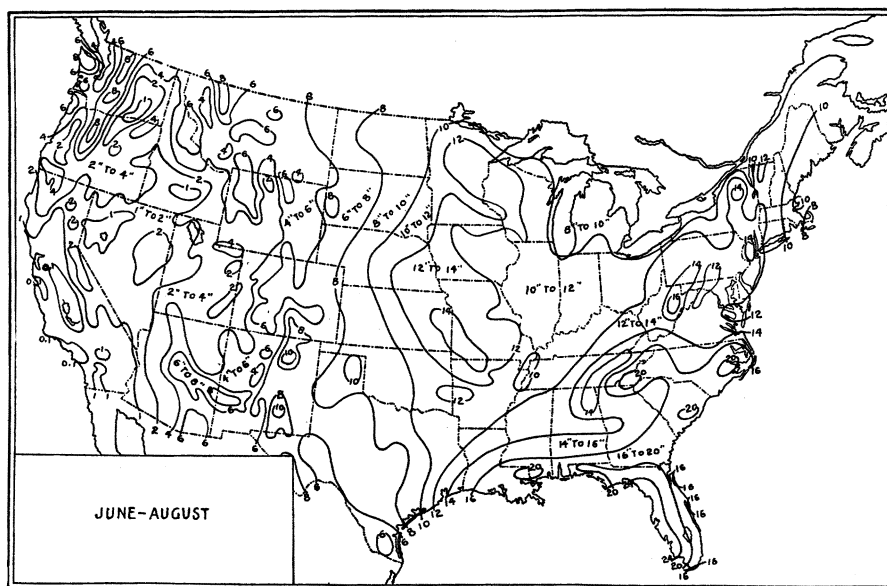


FIG. 3—Map showing the average summer rainfall of the United States. Scale, 1: 45,000,000.

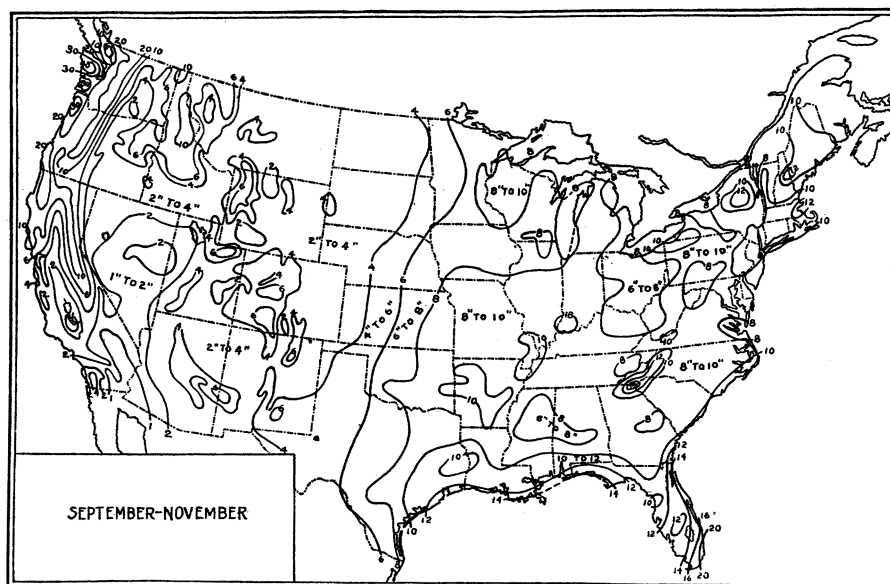


FIG. 4—Map showing the average autumn rainfall of the United States. Scale, 1: 45,000,000.

though more or less local and irregular downpours in the late summer and autumn months.

THE PACIFIC COAST ⁴

The seasonal fluctuation in rainfall on the Pacific slope is, on the whole, the most striking feature on the charts. When the four seasonal charts are examined in their logical order, the winter maximum is seen to grade through a spring with decreasing rainfall to a summer minimum. Autumn follows with a general increase over the whole slope. This is the type of rainfall known as the "Pacific." ⁵ The topographic influences upon the seasonal amounts stand out with remarkable distinctness. In winter considerable portions of the Cascade and Sierra Nevada Mountains have over 30 inches. The northern portion of the Coast Range locally has over 40 inches, with over 50 inches on Mt. Olympus, on the extreme northwestern coast of Washington. The valleys and lowlands have distinctly less rainfall. In Washington and Oregon most of the lower land is enclosed by the 20-inch line, while farther south the Great Valley of California averages below 20 inches; much of it has less than 10 inches, and the southern portion even less than 5 inches. On the immediate seacoast the winter rainfall decreases from north to south from 30-40 inches to less than 6 inches.

Summer is the driest season. The maximum rainfalls on the mountains are nowhere 10 inches, even in the north, while the valleys have roughly 2-4 inches in the north and under 0.1 inch in the southern portion of the Great Valley of California. Spring and autumn are intermediate seasons and have intermediate amounts of rainfall. This marked seasonal migration, poleward and equatorward, of the rainfall conditions on the Pacific coast is still better illustrated on the monthly charts.

From March to July and August there is a striking and interesting withdrawal, up the Pacific coast, of the zone of winter rains, dependent upon the northward retreat of the storm belt and upon the gradual warming of the land. By April the maximum monthly rainfall on the coast in the extreme northwest, is 6-10 inches; 1-2 inches occur in the region about San Francisco, and 0.5 inch on the southern coast. The 1-inch line on the coast is slightly north of San Francisco in May. In June it is on the northwestern California coast. The July map shows the minimum of the Pacific type, i. e. the extreme northward migration of the winter rains. Only a small area in the northwest and the upper slopes of the Cascade Mountains have rainfalls of more than 1 inch. From August through to December the belt of winter rains is moving southward again. Each month shows an extension of the area covered and an increase in the amount of precipitation. Thus for the central California coast, in the district immediately adjacent to San Fran-

⁴ For a map of the climatic provinces which are used as the basis of the following discussion see R. DeC. Ward: Climatic Subdivisions of the United States, *Bull. Amer. Geogr. Soc.*, Vol. 47, 1915, pp. 672-680, Figure 5, on p. 678.

⁵ For a discussion of the rainfall types referred to in this article see R. DeC. Ward: Rainfall Types of the United States, *Geogr. Rev.*, Vol. 4, 1917, pp. 131-144.

cisco, this monthly increase is clearly indicated by the following amounts of rainfall: August, a trace; September, 0.5-1 inch; October, 1-2 inches; November, 2-3 inches; December, about 3 inches.

THE PLATEAU PROVINCE

The Plateau province lies in the rain shadow of the Cascade-Sierra Nevada ranges. Its seasonal rainfall has both marine and continental characteristics. The cold-season rainfall of the Pacific coast may be considered as extending across the mountains into the western portion of the Plateau, causing the primary or secondary winter and early spring maxima of this interior district, these rains being heavier in the north, where there is the greatest cyclonic activity ("Northern Plateau type"). Over the northern plateaus the seasonal amounts decrease from winter to summer, both on the mountains and also over the lower portions of the district. The southern Plateau has its driest seasons in autumn and spring, with the primary maximum in summer ("Southern Plateau type"). As illustrating these points, the following broadly generalized seasonal rainfall amounts for different parts of the Plateau province are here given.

TABLE I—SEASONAL RAINFALL IN THE PLATEAU PROVINCE

SEASON	NORTHERN PLATEAU		SOUTHERN PLATEAU	
	LOWER ALTITUDES	MOUNTAINS (EASTERN)	LOWER ALTITUDES	MOUNTAINS
Winter	About 4"	6"-10"+	1"-4"	4"-6"
Spring	<2"-4"	6"-10"+	<1"-2"	2"-4"+
Summer	<2"-4"	4"-6"+	<1"-4"	6"-8"+
Autumn	2"-4"	6"-10"+	<1"-4"	4"+

THE GREAT PLAINS

The second striking feature on the charts concerns the seasonal fluctuations of rainfall over the Great Plains. In winter the 100th meridian marks about the average western limit of a seasonal rainfall of 2 inches for the eastern United States. In the north, the 2-inch line is well east of the Plains, reaching central Minnesota, while there is a slight extension to the west of the 100th meridian in Texas. The 2-inch line crosses the meridian in Kansas. From month to month, as spring advances, the rainfall lines over the great central lowlands move northward and westward from the Gulf of Mexico. The conditions favorable for increasing rainfall progress inland as the gradual heating of the continent develops a system of inflowing, damp winds which, in a sense, carry the rainfall lines with them. In

March the 1-inch line is about on the 100th meridian; in April the 2-inch and in May the 3-inch line occupies roughly this same position. The spring map shows that the rainfall along the eastern margin of the Plains has increased to three times that of winter (6 inches as against 2 inches). This westward migration is at its maximum in June, when there are monthly rainfalls of more than 3 inches over considerable portions of the eastern and northern Great Plains. The charts thus indicate very clearly the progress of conditions which give the spring and early summer maxima of the "Eastern Rocky Mountain Foothills," and of the "Missouri" rainfall types. The pronounced northwestward extension of these rainfall maxima appears in the trend of the rainfall lines in June.

In July the swing of the sun southward after the summer solstice, and the passing of the conditions which gave the early summer maxima, result in a retreat of the rainfall lines eastward across the Plains. This retreat is greatest and most rapid in the north, where the westward advance was the greatest. In the south between, June and July, instead of a retreat there is a distinct extension westward, over New Mexico and Arizona, of rainfall conditions of 2-4 inches. This is the map evidence of the approach of the late summer maximum, due essentially to local convectional rainfalls, of the "New Mexican" and "Southern Plateau" types. The general eastward withdrawal of the rainfall lines over the Plains continues month by month until winter. The seasonal rainfall amounts along the eastern margin of the Plains are as follows: winter, 2 inches; spring, 6 inches; summer 8-10 inches; autumn, 4 inches in the north to 6 inches in Texas. This great seasonal migration of rainfall conditions over the area west of the Mississippi River, over the Great Plains, so clearly seen on the rainfall charts, brings to mind the economic importance of the warm-season rains in that region. The approach of the time of rainfall maximum is anxiously awaited by the farmers. Upon the proper distribution of the rain, in time and in amount, depends the success of agricultural operations over vast areas of these western states.

THE EASTERN AND GULF PROVINCES

The third large fact illustrated by the charts concerns the rainfall of the eastern United States. It is apparent that, on the whole, the distribution of rainfall throughout the year is generally more uniform in the east than in the west, although there are certain sections of the country east of the Plains where the seasonal fluctuation is well marked. Thus, the westward migration of the rainfall lines in spring and summer, referred to in the preceding paragraphs, is a striking characteristic of the Mississippi-Missouri Valley region. Other seasonal fluctuations shown on the charts are (1) the winter and (early) spring rainfalls of the "Tennessee type," followed by a drier summer and autumn, and (2) the marked (late) summer and (early) autumn rainfalls along the Gulf and southern Atlantic coasts

("Atlantic," "Florida," "North Gulf Coast," and "Texas" types). The generalized seasonal amounts of rain along the Gulf coast are:

TABLE II—SEASONAL RAINFALL ALONG THE GULF COAST

SEASON	FLORIDA	LOUISIANA	TEXAS
Winter	6"—14"	12"—14"	4"—12"
Spring	8"—14"	12"—14"	6"—12"
Summer	16"—24"	16"+	6"—14"
Autumn	12"—20"	12"—14"	8"—12"+

A comparison of all the charts shows a general decrease over the eastern United States as a whole from the warmer to the colder months. Autumn is on the whole the driest season. It further appears that the rainfall charts for the summer months resemble the mean annual rainfall map somewhat more closely than do the charts for the winter months. The warm-season rains, therefore, are the dominant control in eastern sections. The continental type, of late spring, summer, and early autumn rainfalls, covers a larger area and is more important than the cold-season rains. Some twenty-five years ago Harrington calculated the seasonal rainfalls of the United States as a whole. The rainfall of summer is the heaviest; then that of spring, with winter third, and autumn the driest season. The dominance of the continental type of warm-season rains is thus clearly brought out. Observations now available, covering longer periods and from more numerous stations, would give different amounts but would not alter the order of seasons above named.